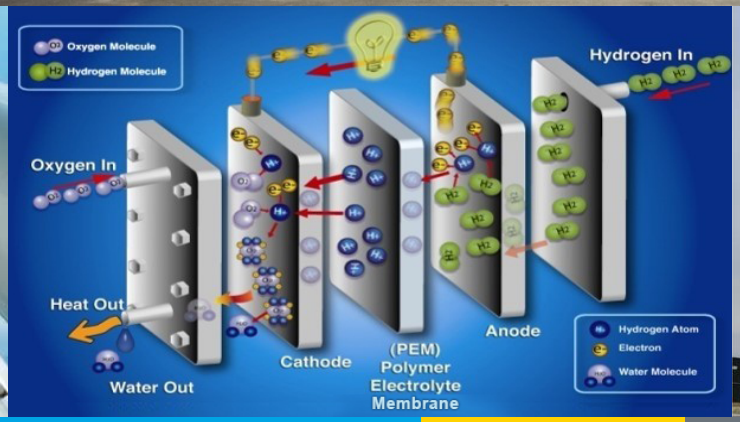
U.S. Department of Energy
Fuel Cell Technologies Office

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



An Overview of U.S. DOE's Hydrogen and Fuel Cells Program

21st International Conference on Solid State Ionics

Padua, Italy June 19, 2017

Dr. Adria Wilson

Technology Manager, Fuel Cells Program
Fuel Cell Technologies Office
U.S. Department of Energy

The Beginning of the DOE Fuel Cell Program…

1970s | **A group from labs, government and industry met at Los Alamos to set the foundation for DOE fuel cell programs**

Lab researchers taught scientists around the world how to fabricate fuel cell electrodes. Group from GM relocated to Los Alamos.

Forty years later, for the first time in history....


Hyundai Tucson Fuel Cell SUV


Toyota Mirai


Honda Clarity

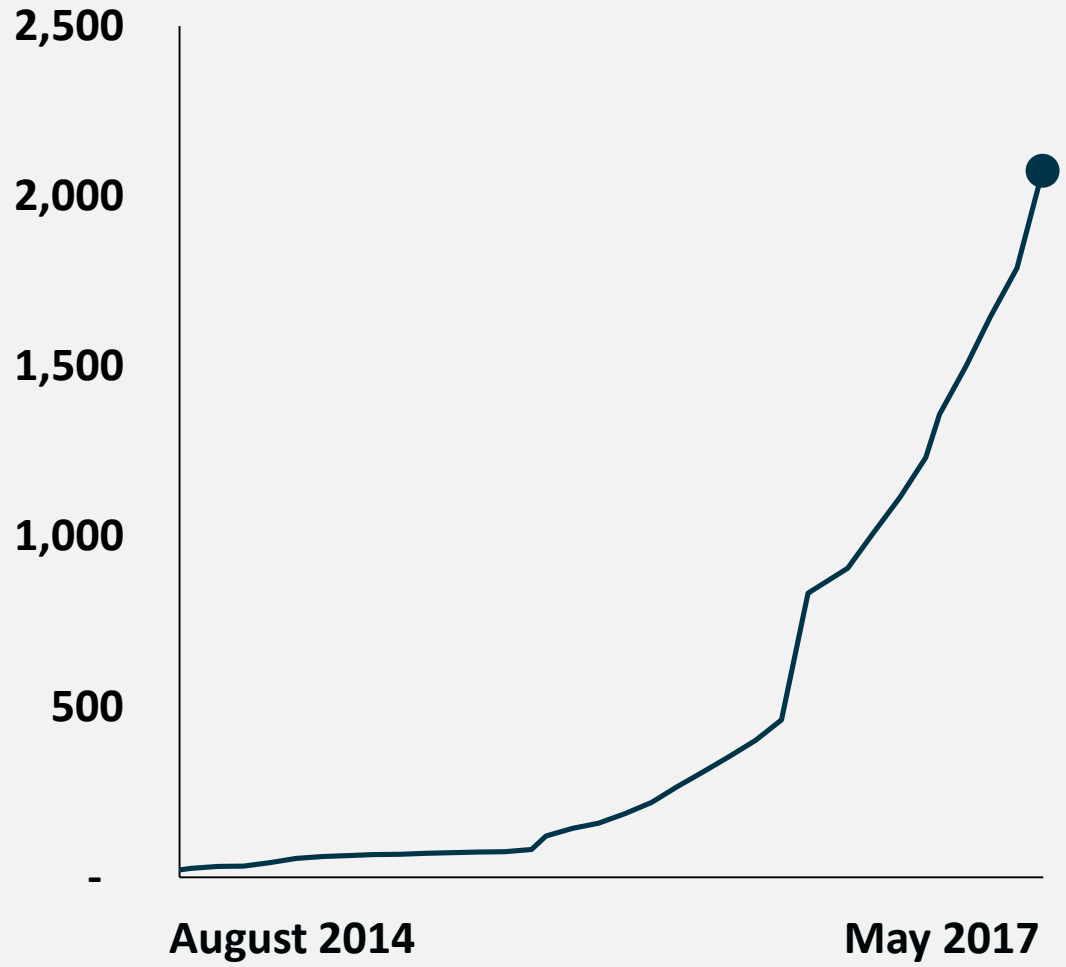
Commercial **fuel cell electric cars are here!**

Power, performance, petroleum-free, pollution-free

- **Refuels in minutes**
- **More than 360 mi driving range**
- **Over 60 mpgge**

U.S. Fuel Cell Car Sales and Expert Outlook

Fuel Cell Car Sales Growing



Note: Cumulative number of vehicles sold/leased. Source: hybridcars.com

2,000 fuel cell cars

sold or leased in the U.S.

78%
of executives

Absolutely or partly **agree that**

Fuel cell cars will be the real breakthrough for electric mobility

KPMG, Global Automotive Executive Survey 2017 (Jan. 2017)

Fuel Cells: Big leaps in the last couple of years

Fuel cell electric delivery and parcel trucks – First of its kind demonstration starting deliveries this summer!

First fuel cell cargo truck at U.S. airport

World's first fuel cell for maritime ports

Fuel Cells: Big leaps in the last couple of years

Fuel cell powered lights at Super Bowl

Fuel cell buses in CA surpass 17M passengers

Industry demonstrates first heavy duty truck

ZH2: U.S. Army and GM collaboration First of its kind

Stationary Fuel Cells- Opportunities Emerging

Data centers require non-stop electrical power

Reliable power is vital at hospitals

Supermarkets- growing interest for reliable power

Fuel Cell Stationary Power in the U.S.

Installations

More than
235 MW
in at least
43 states

Top States

- **By unit size:** DE (30 MW) and CT (14.9 MW)
- **By number of units** CA (480 systems)

Source: DOE Fuel Cell Technologies Office. State of the States Report (2016)

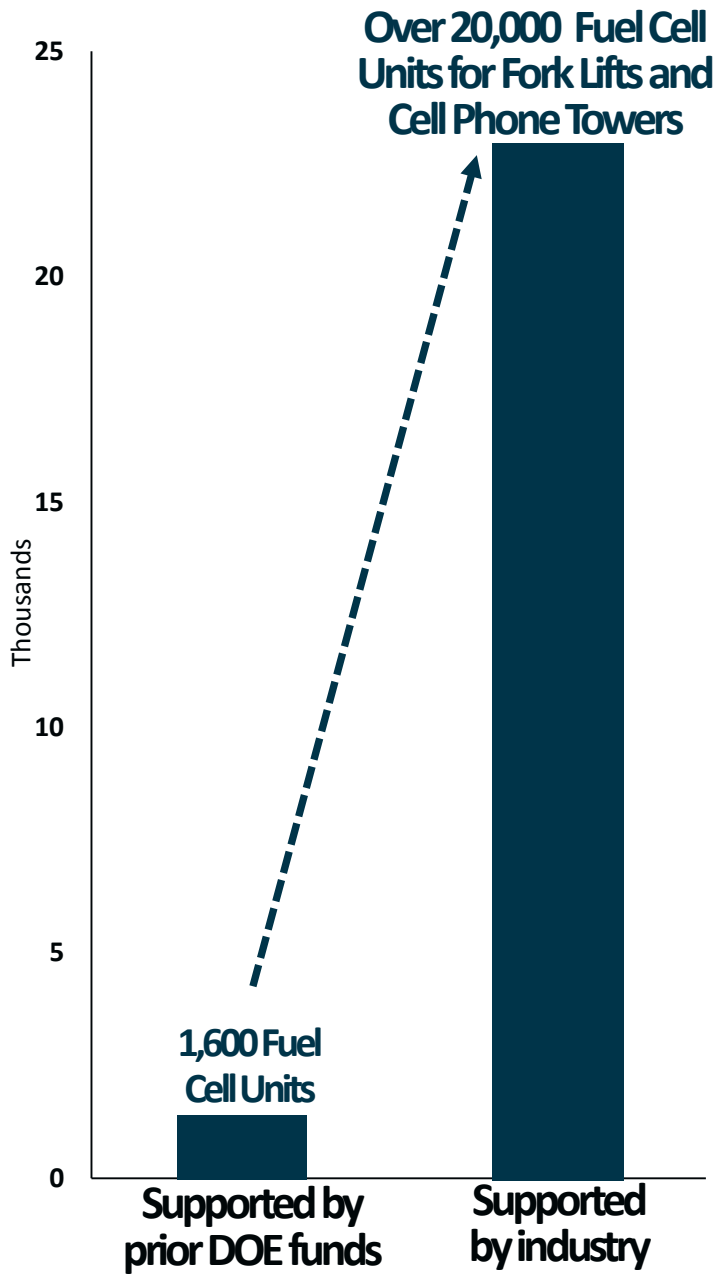
New World Trade Center using fuel cells

Industry Orders for Fuel Cells on the Rise

BMW plant in Greer, South Carolina

Over 15,000 fuel cell forklifts deployed or on order

Approx. 6 million hydrogen refuelings to date



DOE Hydrogen and Fuel Cells Program

Early R&D Focus

Applied research, development and innovation in emerging hydrogen and fuel cell technologies leading to:

- Energy security
- Energy resiliency
- Strong domestic economy

Early R&D Areas

Fuel Cells

- PGM- free catalysts
- Durable MEAs
- Electrode structure performance

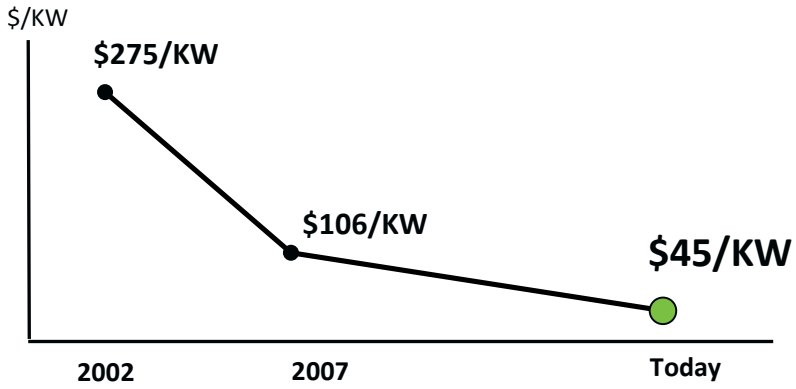
PGM = Platinum group metals

Hydrogen

- Production pathways
- Delivery components
- Advanced materials for storage

Early R&D Impact

80% Lower Fuel Cell Cost



Greater Fuel Cell Durability

4X more hours

of fuel cell lifetime since 2006

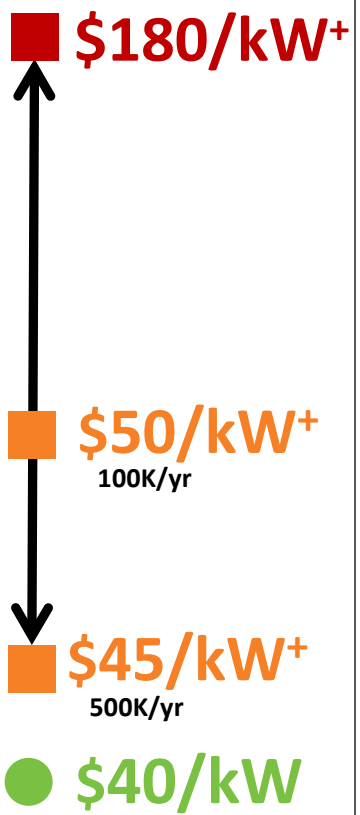
80% Lower Electrolyzer Cost

for H_2 production since 2002

DOE Cost Status and Targets

Fuel Cell R&D

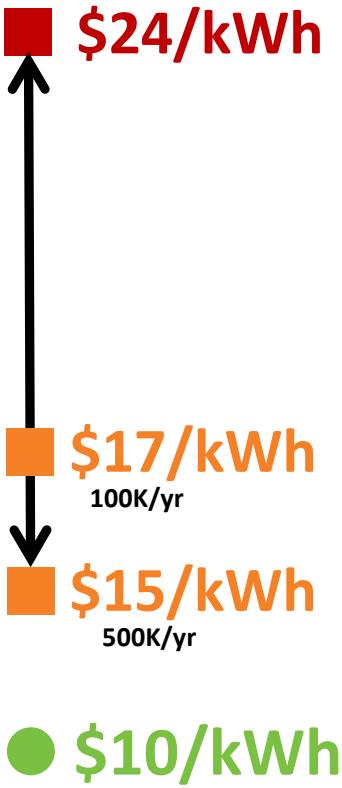
System



Hydrogen R&D

Production, Delivery & Dispensing

Onboard Storage
(*700-bar compressed system*)



2020 Targets | High-Volume Projection | Low-Volume Estimate

*Based on Electrolysis **Based on NG SMR + Preliminary, updates underway
Onboard storage cost status from DOE Program Record 15013

Note: Graphs not drawn to scale and are for illustration purposes only.

Techno-Economic Analysis Guides R&D Portfolio

Fuel Cells

Bipolar Plates
Membranes
BOP
MEA
Frames/Gaskets
GDLs

Focusing on…

Low and Non PGM Catalysts,

Alkaline Membranes

H_2 Station

Storage
Cooling
Dispensing
Other

Advanced Compression

Alternate Approaches

H_2 Storage

BOP/Assembly
Other processing
Resin

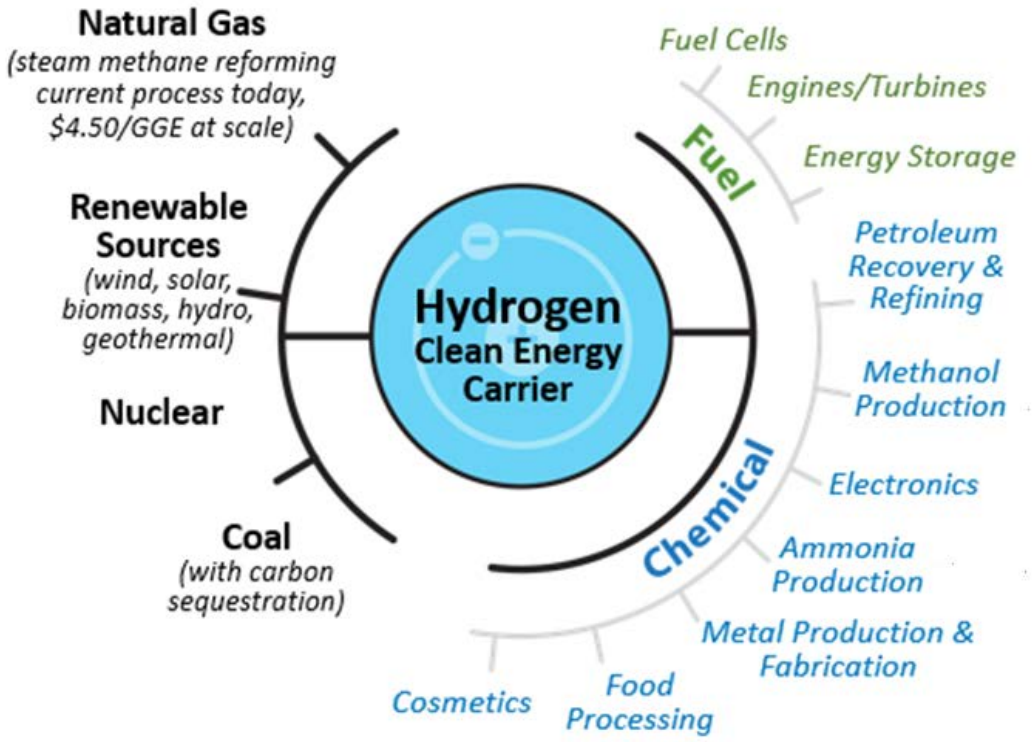
Low Cost Carbon Fiber (CF)

Long term Materials Approaches

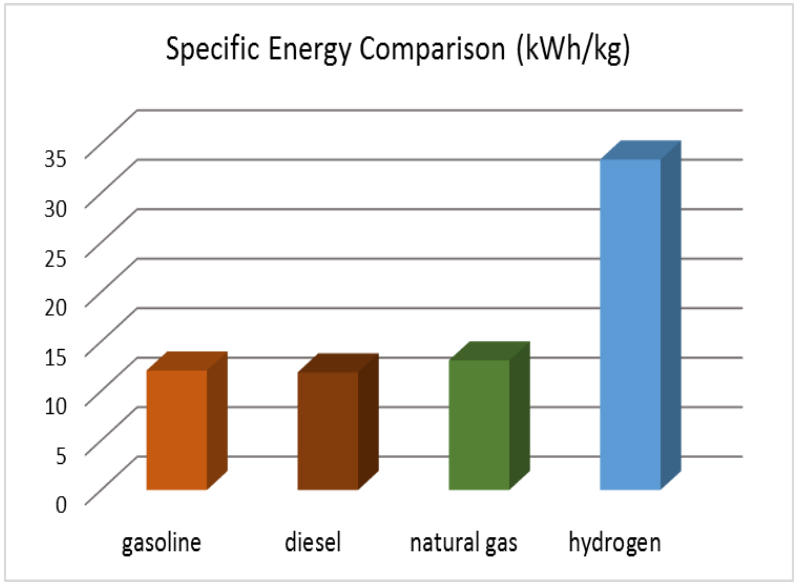
Advantages of hydrogen as an energy carrier

A multitude of sources can be used to produce H_2

Many applications rely on or could benefit from H_2



Very High Specific Energy

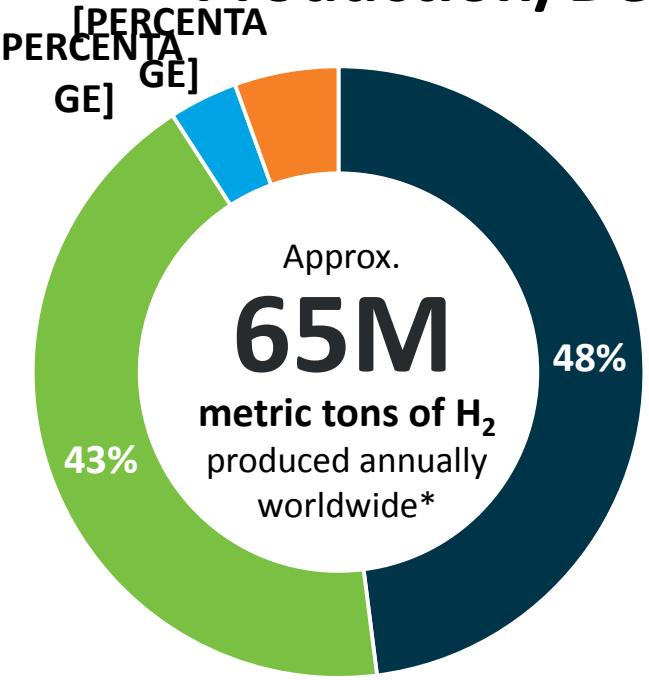


About *three times* more energy by mass than most other fuels!

Hydrogen is a clean, sustainable, versatile, and efficient energy carrier

H_2 Production & Infrastructure: Current Status

Global Annual H_2 Production/Demand



Petroleum Refining

Ammonia Production

Methanol Production

Others including:

- Metal fabrication
- Electronics
- Food Processing

Steam methane reforming of natural gas (SMR): currently most cost-competitive process to produce H_2

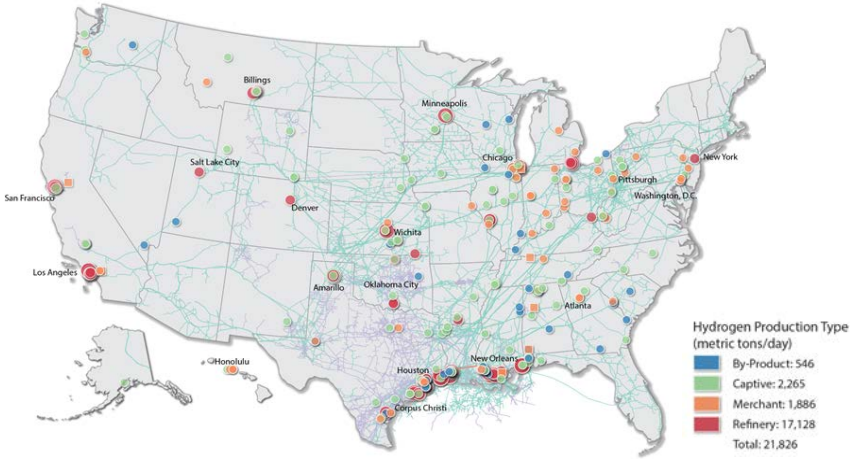
Source: Markets and Markets. Hydrogen Generation Market: Global Trends & Forecasts to 2019, 2014.

Current H_2 Infrastructure:

1,600 miles of H_2 pipeline

>50 H_2 Stations (27 public)

Centralized H_2 production facilities in the U.S.



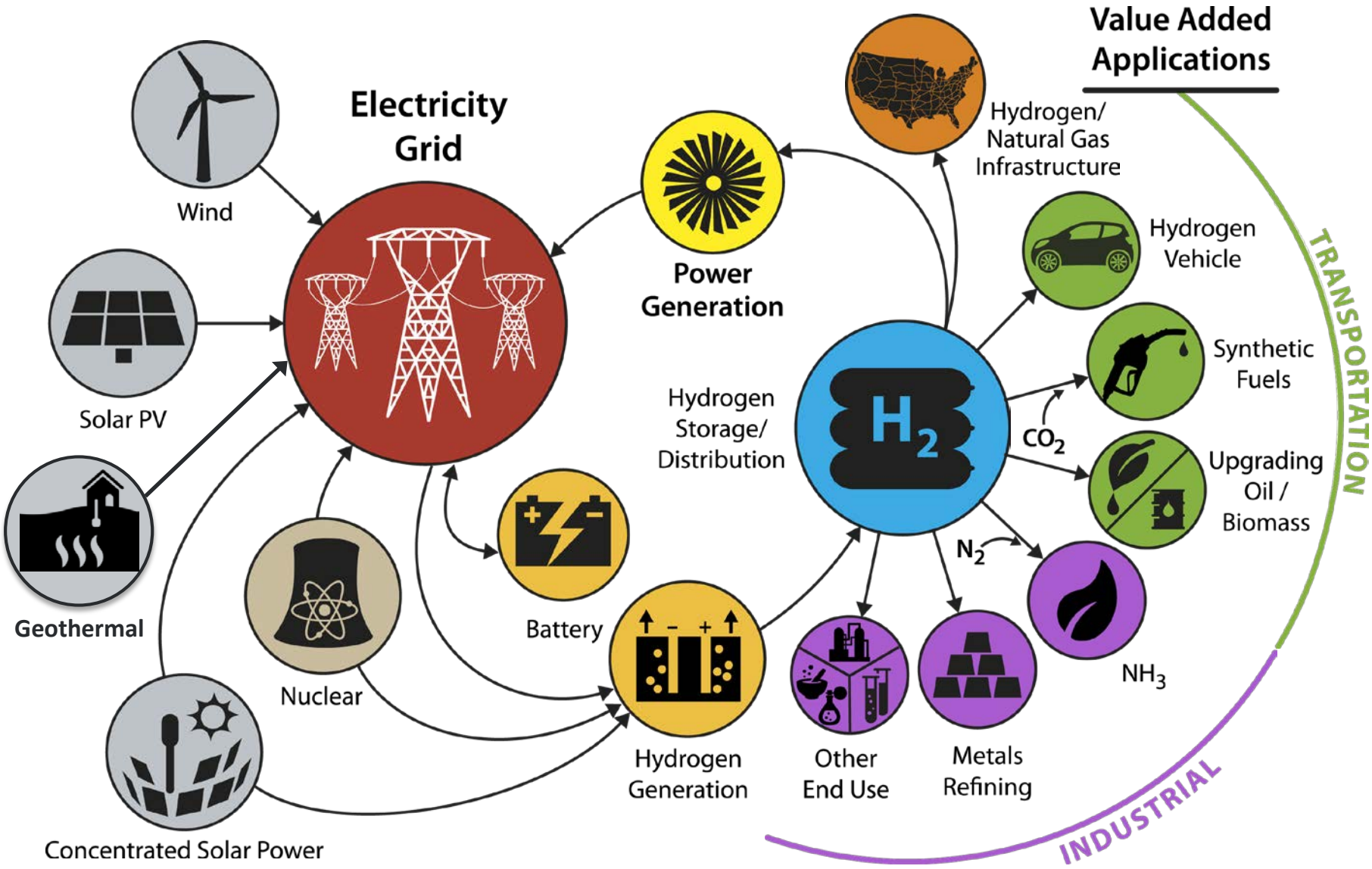
Source: NREL

10 million metric tons of H_2 produced every year in the U.S.

Cost- Competitive H_2 Fuel

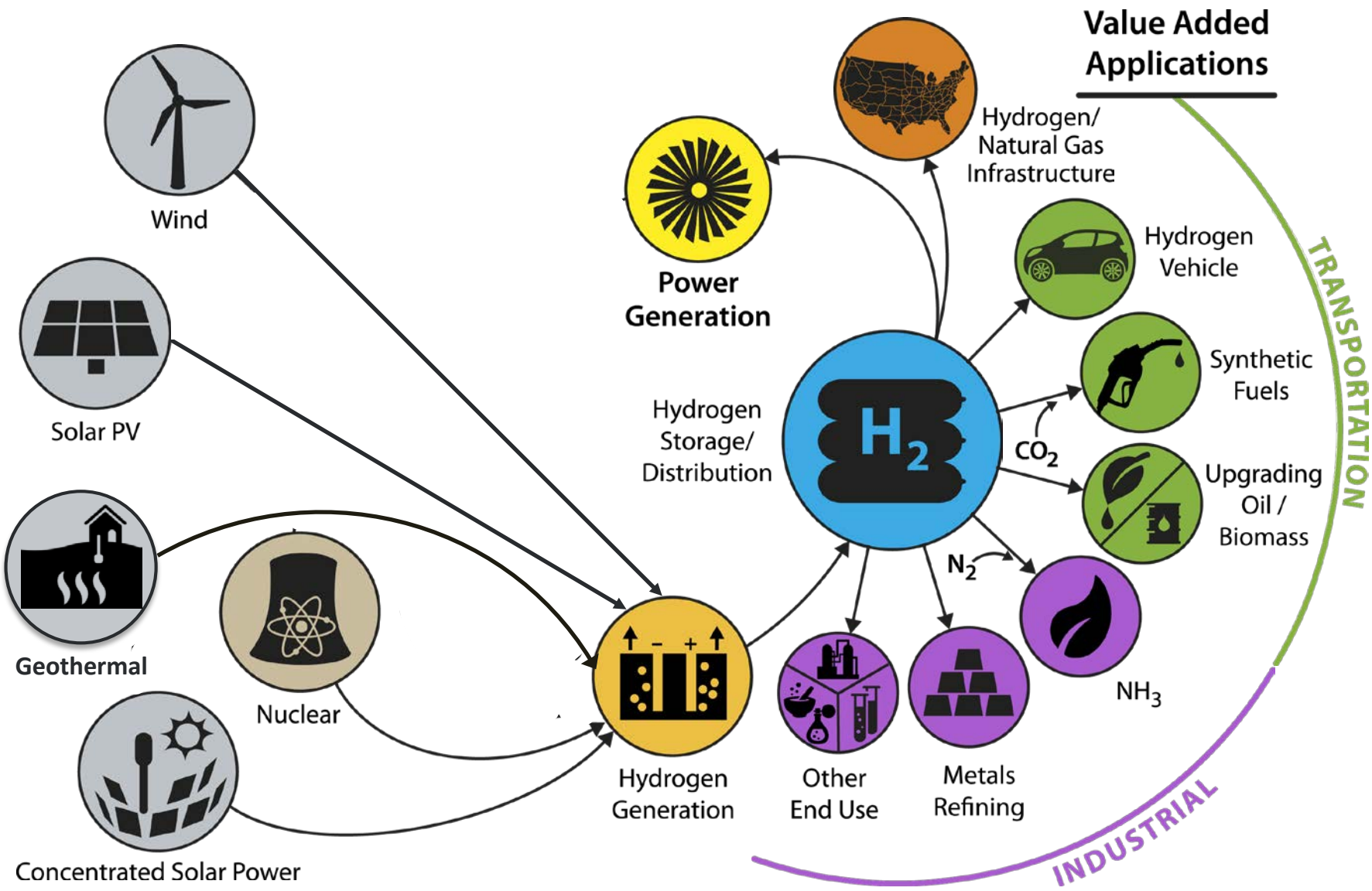
- **H_2 from Natural Gas** through SMR
- **At-scale** production
- **<$2/gge produced** ($4.50/gge delivered)

Conceptual H_2 at Scale Energy System



*Illustrative example, not comprehensive
Source: NREL

Conceptual H_2 at Scale Energy System



Complementing Retail Stations: H_2 Refuel H-Prize

The competition

H2refuel
U.S. Department of Energy

- DOE **$1M prize**
- Focuses on system for **small-scale refueling**
- Authorized in **Energy Independence and Security Act**

More info: hydrogenprize.org

The winning system

simple.fuel.™

- Designed by **three-member team:**
  - Ivys Energy Solutions and McPhy Energy (MA)
  - PDC Machines (PA)
- Produces **H2 via electrolysis**
- Dispenses **1 kg of H_2 in 15 mins** or less
- Allows **700 bar refueling**

More info: www.teamsimplefuel.com
Email: connect@ivysinc.com

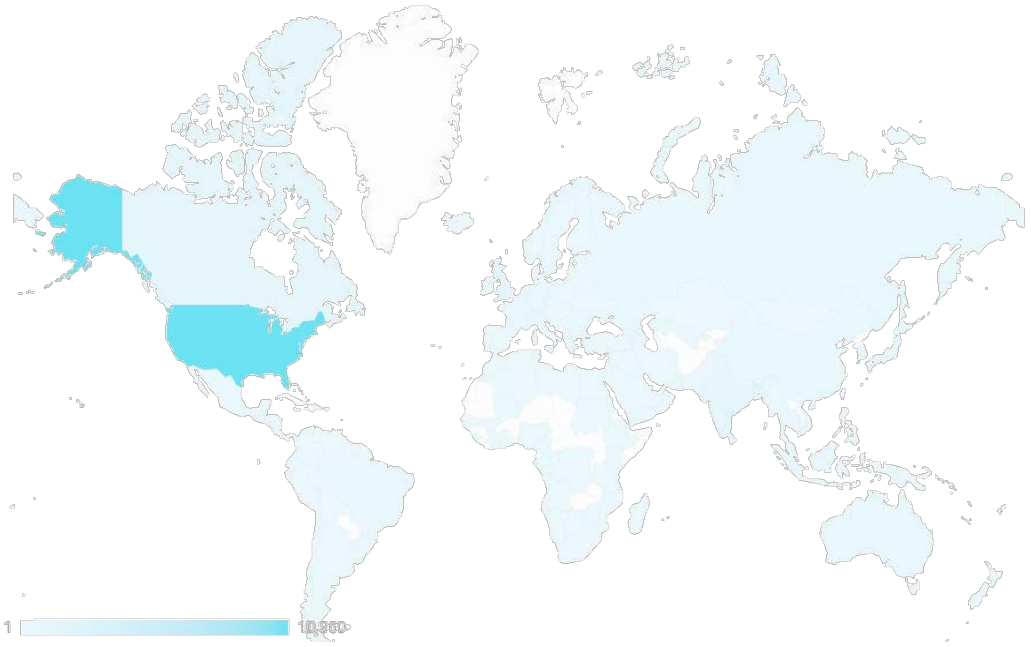
Safety Resources Available

H2Tools.org disseminates information on hydrogen safety

A Global Resource

nearing 150,000 visits since 2015 - 50% are international

Portions translated to Japanese, other languages underway



Hydrogen Risk Assessment Models (HyRAM) for risk analysis under various scenarios

Hydrogen Safety Panel with 400 years of collective safety expertise, collaborating worldwide to advance safety, codes & standards

Nominations for experts now being accepted
Contact: hsp@h2tools.org

Summary

- **Enable early R&D innovation**
  - **Hydrogen fuel**
  - **Fuel cells**
  - **H2@Scale**
- **Leverage activities to maximize impact**
  - **Enable infrastructure and cross-sector impacts**
  - **Partnerships- other agencies, industry, states, etc.**
  - **Collaboration on safety R&D and information sharing**

Upcoming Events

Save the Dates!

National Hydrogen & Fuel Cell Day | 10·08

Participate in social media using
#HydrogenNow #FuelCellsNow

H2@Scale Session at the Fuel Cell Seminar
November
Long Beach, LA

AMR and Industry Expo
June 2018 (to be confirmed soon)
Washington, DC

Thank You

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